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Deliverable title	Roadmap for emerging networks
Description	Assessment of networks and gap analysis that highlights opportunities for development over three and ten year timescales.
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Work Package title	Cross-cutting issues and emerging networks
Lead beneficiary	NERC
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Stakeholder engagement <u>relating to this task</u>*

WHO are your most important stakeholders?	☐ Private company If yes, is it an SME ☐ or a large company ☐ ? ☐ National governmental body ☐ International organization ☐ NGO X others Please give the name(s) of the stakeholder(s): Marine and environmental research community Statutory marine monitoring agencies
WHERE is/are the company(ies) or organization(s) from?	☐ Your own country ☐ Another country in the EU ☐ Another country outside the EU Please name the country(ies): Research : Global Monitoring: National Industrial: Predominantly USA
Is this deliverable a success story? If yes, why? **If not, why?**	☐ Yes, because ..... Comprehensive and timely review of emerging biogeochemical and biological observing networks. Including opportunities in industrial infrastructure.
Will this deliverable be used? **If yes, who will use it?** **If not, why will it not be used?**	☐ Yes, by …… Emerging networks by their nature are underutilised. This deliverable will be used by academia, SMEs and the wider industry to identify opportunities and how best to target effort to realise the potential that has been identified.

Introduction

Whilst the AtlantOS project is directed towards bringing together the existing, but currently disparate observing programmes in the Atlantic Ocean, there are still some gaps in terms of requirements for addressing the collection and curation of data around the Essential Ocean Variables. This deliverable will identify gaps and emerging observing networks. Here we use the term emerging network to classify science areas that are starting to gain importance with respect to EOV's and their measurement and curation, or are existing small scale programmes or communities that might become more important in the future if we can find means of enhancing the collaboration among investigators/groups, increasing resources to the area or using new technological developments.

In the AtlantOS project we have identified a number of areas in which there are gaps in our knowledge and where opportunities exist to enhance current small-scale networks.

The scope of this document is to assess these networks, based on where we are now and where the networks could be in three and ten years' time, respectively. An assessment of the state of the existing networks is useful to identify the level of international organisation and potential for further development in the future. We identify opportunities where synergies are possible with more established global projects, and where small levels of investment in resource and time for governance and coordination can productively and realistically develop the networks. We also identify if there are ways to develop coordinated approaches to metrology technology development.

For this analysis, the networks have been allocated to one of the three groups outlined below.

1. Emerging biogeochemical networks

In an assessment of the current state of emerging networks for biogeochemical measurements we must first understand which emerging networks have been identified. Once the networks are understood we need to assess what measurements can be recorded by the networks. The Global Ocean Observing System (GOOS) (www. http://goosocean.org/) panels have identified a list of EOV's for biogeochemical species in the ocean. These are dissolved oxygen (DO), inorganic macronutrients (MN's), carbonate system parameters (CS), transient tracers (TT), suspended particulates (SP), nitrous oxides (NO_x), carbon isotope (^{13}C) and dissolved organic carbon (DOC). GOOS have specialist panels that have collated information around each of these EOV's. The emerging networks identified for the assessment by GOOS were profiling floats, gliders and drifters, moorings and ships of opportunity. For the scope of this deliverable we have summarised the information about future (emerging) observing networks, including the maturity (mature, pilot, concept) of their analytical techniques, the state of current deployments on various platforms that offer ranges of temporal and spatial coverage, and data/metrology oversight (Table 1).

Table 1. A summary of the main biogeochemical EOV's related to their use on the commonly used platforms.

EOV	Analytical approach	Profiling floats	Glider/Drifter	Surface/sub surface	Ship of opportunity	Data/metrology quality control

				moorings		
Dissolved Oxygen	Mature	Pilot/mature	Mature	Mature	Mature	Floats-pilot, climatology / in situ calibration procedure developed Repeat hydrography-mature
Macro-nutrients	Better sensors needed	Pilot	Pilot	Pilot	Mature	Pilot level
Carbonate system	Standard methods well understood, sensors needed	Pilot	Pilot/concept	Concept	pCO2 Mature, others at concept level	Mature laboratory / ship based procedures. In situ calibration currently problematic (pH only and drift still evident)
Transient Tracers	Mature but no in-situ sensors	None	None	None	Concept	Mature
Suspended Particulates	Mature	Concept	Mature	Concept	Mature	None
NO_x	Mature but no sensors	None	None	None	Pilot	Data collated under MEMENTO project[a]
^{13}C	Mature but no sensors	None	None	None	None	Limited
DOC	Mature but no sensors	None	None	None	None	CCHDO, BATS, HOTS, CDIAC

[a] https://memento.geomar.de

This table is useful for assessing the likelihood that there will be the ability to make the measurements required as identified by the GOOS panels. The AtlantOS project has developed a roadmap for the development of sensors and other enabling technology for earth observations, this can be found in D6.1

Profiling floats

Currently there are over 3700 Argo profiling floats deployed in the worlds' oceans. These are primarily measuring temperature, salinity and velocity over the top 2000 m of the water column, though deep diving floats are being deployed at the pilot level. The plan through Biogeochemical-Argo network (Bio-Argo) is that these platforms will be instrumented with biogeochemical sensors for pH (ISFET), oxygen (Optode), nitrate (UV spectroscopy), chlorophyll (fluorescence), suspended particles (backscatter) and downwelling irradiance (optical sensors). . The initial plans for the network are to deploy up to 600 floats within 5 years in the oceans, and a full implementation plan is in development. The initial budget estimates to deploy and maintain the floats are on the order of $1.5m per year on top of the Argo network cost. Data management and quality control systems will be developed but will follow the approaches of the Argo program.

Gliders and drifters

The glider community is becoming more organised and there are some funded projects at the national level and international level, particularly in Europe. There is a generally accepted data management process that was developed in previously funded projects (GROOM, and EGO-COST), and data is transmitted by GTS and submitted to global data repositories such as COPERNICUS. Gliders are now identified as part of the GOOS. By contrast, the European drifter community is not as well developed but there is a Global drifter program database operated by NOAA (http://www.aoml.noaa.gov/phod/dac/index.php).

Surface and sub-surface moorings

In the European context the largest coordinating body for fixed moorings is the Fixed point Open Ocean Observatory network (http://www.fixo3.eu) funded by the European Union FP7 programme. This project builds upon funding from the FP7 projects EuroSITES, ESONET and CARBOCEAN. The project is predominantly a coordination action to ensure that the observatories, operated mainly at the nationally funded level, have a harmonised approach to technology development, shared management procedures, and data services and products. The project has done a full cost-benefit analysis (http://www.fixo3.eu/download/Deliverables/D6.6%20Cost-benefit%20analysis%20report.pdf) of the existing international observatories and has also generated a generic costing sheet for fixed-point observatories. In the wider international context the coordinating body of the fixed-point observatories is the OceanSITES project, which covers 30 surface and 30 subsurface arrays in the worlds' oceans. The data is centrally collated and follows international data format standards. OceanSITES is a part of GOOS.

Ships of opportunity

The Ships of opportunity programme (SOOP) is an international effort that began by taking Expendable Bathythermographs (XBT's) from vessels including container ships, cruise ships and research vessels as these transit the worlds' oceans. In addition to the XBT programme, there is now a network of ships carrying automated CO_2 measurement systems, for example as part of the NOAA funded SOOP-CO2 project but also including other groups (e.g. Professor Doug Wallace Dalhousie, Canada). The SOOP Implementation Panel ensures that all of the data generated is broadcast over the Global Telecommunications System (GTS) to national data centres, and makes an annual report on the quality of the data. SOOP comes under the control and funding of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) a joint body between the World Meteorological Organization and the Intergovernmental Oceanographic Commission.

2. Biological observing networks

Whilst one of the acknowledged gaps in our observation of the oceans is around the biological domain there is still a great deal of debate about what can be considered biological EOV's. The GOOS Biology and Ecosystem Panel (GOOS Bio-Eco) was established to decide what essential biological and ecosystem variables should be included in the global ocean observing system. The panel has proposed nine biological EOVs split over two components; those that inform the status of functional groups: phytoplankton biomass and productivity, incidence of harmful algal blooms (HAB's), zooplankton diversity, fish distribution and abundance, apex predator distribution and abundance and those that inform the health of the living ecosystem: seagrass cover, macroalgal cover, live coral cover, mangrove cover. From these nine EOVs two (zooplankton diversity and live coral cover) were consider at a pilot stage while the other seven have been considered merely at concept stage recognising that still a lot of work has to be done to operationalize them.

The networks around these biological observations are much less well developed than the emerging networks considered above for the biogeochemical cycles and measurements. The GEO (Group on Earth Observations) is developing the 2017-19 work programme ((https://www.earthobservations.org/documents/work_programme/geo_2017_19_Work_Programme.pdf) in which a number of efforts have been identified to develop observatory networks for the Biological and ecological EOV's. Explicit reference is made to Sustainable Development Goal (SDG) 14 – Life below water, and the role that GEO must take in that and the other SDG's.

In the framework of GEO BON flagship (GEO Biodiversity Observation Network) formed in 2008 a thematic network named MBON (Marine Biodiversity Observation Network) was formed in 2016. MBON is the follow-up of the Marine Ecosystem Change working group from GEO BON first implementation plan. It was created to help provide the information and knowledge needed to inform the progress towards internationally agreed targets as the global 2030 targets of the UN Sustainable Development Goals (specifically SDG 14), the 2020 Biodiversity Aichi targets of the Convention on Biological Diversity (CBD), and international efforts as the Intergovernmental Platform on Biodiversity and Ecosystem Services (UN IPBES), the second World Ocean Assessment, and provide guidance to the current negotiations for a new legally-binding instrument under UNCLOS on the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction.

The goal of MBON is to build a community of practice for the collection and curation of marine biodiversity information and to establish practical measures of biodiversity, defining past or current baselines against which to evaluate change. It will also implement monitoring programs that use standard protocols, and facilitating the comparison of observations collected in different regions.

The MBON mission is to focus the international operational agencies that constitute the GEO to facilitate the planning, implementation, and functioning of a network of marine biodiversity observation efforts. These efforts include facilitating linkages between research and operational groups on an international scale. They also focus on the development of marine Essential Biodiversity Variables (EBVs) to complement the broader Essential Ocean Variables (EOVs) defined jointly with the Global Ocean Observing System.

Furthermore GOOS Bio Eco, MBON and the Ocean Biogeographic Information System (OBIS), have already made an agreement to work together to build a sustained, coordinated, global ocean system of marine biological and ecosystem observations. The aim is to enhance existing observation scope and capacity, further identify essential biological ocean variables and collect the necessary observations to best assess ocean living resources, while enhancing global capacity for long term global marine biological and ecosystem observations. Resulting information from this network will be delivered through an open access, integrated and quality controlled database and will support management decisions and relevant science and societal needs.

At the moment there are three pilot MBON projects funded by the US at around $6 million, with the aim of creating and optimising a series of different marine biodiversity observation systems. This and other existing initiatives as the Marine Global Earth Observatory (MarineGEO), directed by the Smithsonian's Tennenbaum

Marine Observatories Network (TMON) a long-term, worldwide research program to focus on understanding coastal marine life and ecosystems that led to the first steps of MBON were strategically placed in the Americas. But other initiatives and networks as e.g. the Continuous Plankton Recorder (CPR a monitoring program started 85 years ago in the UK and now the Global Alliance of Continuous Plankton Recorder Surveys) and other national and international initiatives are being brought together to build the global MBON. In Europe there has been some developments and workshops have been organised with AtlantOS and GEO BON in Germany to discuss and draft the structure and implementation plans for the global MBON. The implementation plan for this network is now being drafted.

Understanding global marine biodiversity and how this is changing is challenging but advances in genomic and metagenomic approaches could provide a valuable tool.

Case Study 1. Genomic and metagenomic networks

While no official deliverables regarding microbial observations exist in the AtlantOS DoW, there is considerable opportunity to cultivate a self-sustaining community of practice focused on harmonising marine microbial and molecular observation. Within this domain, several AtlantOS partners are conducting programmes which are deploying similar technologies and developing similar metrology and data processing workflows. These include the AWI's Frontiers in Arctic Marine Monitoring (FRAM), the MBARI Marine Biodiversity Observation Network (MBARI MBON), ATLAS, A trans-Atlantic assessment and deep-sea ecosystem-based spatial management plan for Europe, and the development of microbial/(meta)genomic sampler technology and molecular metrology best practice in WP6 of AtlantOS. In particular, these efforts employ advanced and often novel methods involving the extraction, processing, and archiving of nucleic acids from environmental materials coupled to the use of next-generation sequencing and bioinformatic workflows to generate ecological insight.

Given the existing overlap, establishing a structured, coordinated network of microbial and molecular observatories to facilitate knowledge exchange and systematically agree upon best practices would be both readily achievable and of great value to the observing community and its stakeholders. An identifiable consortium of microbial and molecular observatories can serve as a coordination focus and facilitator as techniques and capabilities advance and more ecological observatories inevitably adopt "omics" (meta-genomics, -transcriptomics, -proteomics, etc.) technologies, promoting controlled integration of omics data into future EOVs. Such a body would address the unique case of integrating these methods into multidisciplinary, long-term observatory settings and be better prepared to coherently interface with national and international monitoring initiatives as well as other stakeholders. Further, this consortium would facilitate the emergence of consensus on key issues such as how to ensure comparability given technological and methodological shifts and how to archive sample material for re-analysis (e.g. via coordination with the Global Genome Biodiversity Network). Members could provide one another with internal cross-validation of results and methods in aid of controlling technical variance introduced into monitoring results. The consortium would also provide a means to efficiently communicate the 'omics observing community's findings, recommendations, and positions via coordinated peer-reviewed publications and/or whitepapers.

Fortunately, a considerable amount of work has been done in establishing and operating such networks. A notable example is the Genomic Observatories Network (GOs Network), which recently emerged from the Genomic Standards Consortium

(GSC). The GOs Network mission statement largely echoes the objectives of AtlantOS participants using omics technologies:

- *To build a global network of premier research sites working to generate genomic biodiversity observations that are well contextualized and compliant with global data standards.*
- *To encourage a set of long-term, place-based, DNA-centric programs that quantify biotic interactions in an ecosystem and develop models of biodiversity to predict the quality and distribution of ecosystem services.*
- *To provide training, technical assistance, resources, and best practice guides as a learning platform for sites and organizations wishing to carry out genomic observations, particularly new sites in developing countries (many of which have very high and/or vulnerable biodiversity)*

Indeed, the GSC and GOs Network may provide the framework needed to improve and sustain coordination between the microbial observatories within and beyond AtlantOS. Over the 11 years since its foundation, the GSC has served as a rally point for omics researchers to standardise the reporting of metadata associated with sequences in public repositories. This formal structure facilitated a series of GSC projects such as minimal information checklists (including The Minimum Information about a Genomic Observatory [MIGO]) which have helped coordinate not only reporting, but also methodological standardisation of initiatives such as the microbial observations at Plymouth Marine Laboratory, the Moorea Biocode project, the Northern Temperate Lakes LTER, and the Earth Microbiome Project. The GSC also provided the framework for launching international projects such as the Ocean Sampling Day (OSD) series, which employs standardised methodologies and reporting based on the GSC's previous work and consensus building. Indeed, through its efforts, yearly meetings, affiliated journal (Standards in Genomic Science: ISSN 1944-3277), and growing membership, the GSC has now interfaced with large-scale projects such as TARA oceans (and its successor, the Oceanomics project), gained support from the European Bioinformatics Institute (and other INSDC bodies), and attracted interest and collaboration from continental-scale observatory projects such as NSF's National Ecological Observatory network (NEON) and the Critical Zone Observatory (CZO).

It is clear that the emerging networks comprising the omically enabled observatories in the AtlantOS network face unique challenges; however, it is also evident that there is great overlap with the scope of established networks. In the short- to mid-term it would be desirable to approach the GOs Network (and its associated networks) and explore how to fuse these models synergistically and sustainably. Perhaps a co-evolution of the MBON framework (nested within GEOBON) and GOs would yield a rapid route towards creating a consortium able to generate evidence-based and robust community standards for omically enabled ocean observation. With these in place, long-term data will be far more actionable and amenable to synthesis in order to address biodiversity challenges in the 21st century.
[1]

Case Study 2. The Ocean Tracking Network (OTN)

Another proposed EOV is the abundance and distribution of marine fishes and apex predators. Despite the great ecological and economic (both directly and indirectly via ecosystem services) importance of marine fishes, sharks, marine mammals and other apex predators, little is still known globally about their survival, movements and

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migrations, habitat use, and response to the changing ocean. This knowledge gap is a clear impediment to the managers and policy makers striving to balance future “Blue Growth” developments in the ocean with sustaining healthy marine ecosystems and the current human activities that depend upon them. The Canadian-led Ocean Tracking Network’s (OTN) is an international marine animal tracking initiative created in 2009 aiming to achieve a global tracking platform capable of providing the required information about animal movements and distributions. OTN has leveraged new equipment deployments and its internationally recognized data system with existing local and regional scale animal tracking networks to substantially increase the electronic telemetry and oceanographic monitoring equipment in all of the world’s five oceans. The telemetry networks are composed primarily of acoustic receivers maintained by local researchers. This global receiver infrastructure addresses local questions, but also provides a capability to comprehensively examine the local-to-global movements of tagged marine animals such as sharks, sturgeon, eels, and tuna, as well as other marine species including squid, sea turtles, and marine mammals.

OTN is a system of GOOS and therefore clearly identified as a global ocean observing system. It is also an explicit contributor to the AtlantOS DoW. In particular, it is the centrepiece to organize the existing community of marine animal trackers in Europe via the newly created European Aquatic Animal Tracking Network (EAATN). This community has achieved international recognition for its work in marine tracking research but is not yet organized to the point of benefiting from the expanded assets of a network approach to data collecting and sharing.

The main challenges and opportunities in these emerging networks lie in the links to, and inter-operability with, environmental (ocean) monitoring networks, and in the articulation between the different technological tracking platforms used (e.g. acoustic versus satellite telemetry) and science communities. Both aspects are crucial to achieve the needed global biological observing network. Strong synergies are possible among the tracking community/OTN and other components of AtlantOS. For example, acoustic receivers can be placed on observing platforms for physical oceanography (e.g., buoys or gliders), creating novel platforms for oceanic observation. “Animal oceanographers” can also carry acoustic telemetry systems. Large scale funding is another key aspect given the traditional substantially smaller magnitude of funding between this type of biological research compared with the classical oceanographic research and their observation networks. The scale of funding needed to deploy and maintain a large scale Atlantic observation network based on fixed (e.g. acoustic receivers on buoys) and mobile (e.g. satellite tagged animals and receivers deployed on animals/drifting floats/gliders) could be high. However, with their potential as both a scientific and societal flag project to bring together scientific communities and efforts across the Atlantic, this network is not without merit. Cost savings by using and augmenting existing mature networks may be possible.

3. Networks primarily developed for industrial applications

Presently there are more than a million km of telecommunication cables along the ocean floor. There is an interest in using these cables for scientific purposes. There has been a joint task force (JTF) established in 2012 by the International telecommunications Union (ITU), the IOC and the WMO to investigate the use of these cables for ocean and climate monitoring and disaster warning (http://www.itu.int/en/ITU-T/climatechange/task-force-sc/Pages/default.aspx). The group is developing a strategy and a roadmap looking at the deployment of submarine repeaters equipped with marine sensors. As part of the work the JTF produced a plan looking at the costs and possible funding routes for such a system. Initial estimates are that the development of sensors would be between $1-6 m and between $1- and $20 million for an initial demonstration project. The group also looked at the possible routes for obtaining this funding and concluded that one or more of the international development agencies such as the World Bank would probably be the most likely source of funding.

There are a large number of active and inactive offshore installations associated with the oil and gas industry. A fledgling network based around these operations is involved with using oil company ROV resources to film the deep-sea biology associated with their offshore facilities. The SERPENT project (http://www.serpentproject.com) brings together the major offshore oil and gas companies and a large number of academic partners around the globe. The work they have done so far has led to an increased understanding of the biological communities around these offshore platforms. To date the work has been funded predominantly by the oil and gas operators and provides a useful model for other emerging networks of this type. The involvement of Equinor in the funding of the LoVe observatory to the Institute of Marine Research in Norway is a promising step, where a company directly funds such an observatory with a clear plan for future expansion. The development of the NEPTUNE array, a joint US/Canadian cabled network in the Eastern Pacific shows how powerful international collaboration can be, and whilst not a direct use of an existing industrial infrastructure it has adopted technology from the industrial sector.

Document Update 2018

It was always the intention that this would be a living document and would be updated` throughout the project. To that end a table was developed addressing key parts around the development of observation networks, and sent to members of the emerging communities. The table (Table 2) is arranged by network and then a series of rows identifies key features of the network and whether they are in place e.g. an established secretariat, sustained funding, business plan developed etc.

From the feedback it is clear that the various networks are at different stages of development; from the Ocean Tracking Network which can be classed as an established network, to some of the new networks like the Kelp system ecological network. To enable the development of these emerging networks it is necessary to link data products to end-users, as demonstrated by the ARGO network where a number of global weather services now rely on the data from the ARGO network of floats. This allows a means of valuing the data or products from the network which makes it easier to garner support for the networks.

It is possible to provide small amounts of support than can be then leveraged to gain greater funds, for instance the AtlantOS project has already supported the development of one network around seabed mapping by funding The Atlantic Seabed Mapping International Working Group with the Atlantic Ocean Research Alliance. This type of ad hoc funding for projects will be used where possible but there needs to be committed, underpinning support for many of the networks if we are to have a linked efficient observing network for not just the Atlantic, but the whole of the worlds' oceans. In all likelihood this will be through a combination of national government funds, international funding bodies, the formation of novel funding routes such as 'blue-bonds' recently issued by the Government of the Seychelles in collaboration with the World Bank, and through industry.

Conclusions

As we look towards the establishment of a truly global observing system the AtlantOS project is investing a lot of effort into establishing where the gaps are in the observations, identifying technologies that can enhance existing networks and means of linking the sometimes disparate smaller networks into larger more established observation programmes. It is clear from the table that those networks that link to existing networks such as the biogeochemical ARGO and the Ships of opportunity networks are generally more developed, and that the support of organisations such as GEO and JCOMM are important. Some of the networks are currently limited by existing technologies, an example of this is the use of the telecommunications cables that cross the worlds oceans, all of the networks would benefit from underlying developments in sensor technology to enable a better collection of useful data. We must support the development of good practice with regard to metrology and data management so ensure adoption by the wider community of stakeholders.

The future of ocean observing at an interesting point in time, we can point to successful observing networks such as the existing ARGO array and show a direct value to stakeholders. The more information we gather from the marine system the more able we are to move towards a truly sustainable use of the oceans, key for SDG 14.

Sector — **Emerging biogeochemical networks**

Network	*Profiling floats*	*Gliders*	*Eulerian Observatories*	*Ship of opportunity*
Organised community (Y/N)	Yes	Yes, in development through EGO and GROOM, see below	Partly through EMSO, RAPID & PIRATA	Yes through the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) through the VOS Panel. The SOOP programme is a key part of the ICOS network for carbon system measurements (https://www.icos-ri.eu/home)
Website (link)	http://www.argo.ucsd.edu/About_Argo.html	https://www.ego-network.org/dokuwiki/doku.php?id=public:goosgstt	http://www.fixo3.eu/ http://www.rapid.ac.uk/rapidmoc/ https://www.pmel.noaa.gov/gtmba/pirata	http://sot.jcommops.org/vos/
Organisation document link / attachment		http://www.groom-fp7.eu/lib/exe/fetch.php?media=public:deliverables:groom_final_report_publishable.pdf	N/A	There is a ships of opportunity implementation Panel with details at the following website: https://www.jcomm.info/index.php?option=com_oe&task=viewGroupRecord&groupID=107 There is an updated list of the ships involved in the network on the following pages: http://www.wmo.int/pages/prog/www/ois/pub47/pub47-home.htm
Secretariat established? (Y/N)	Yes	No	Previously partly under FixO3. In future under EMSO, RAPID and PIRATA	No but coordinated through JCOMM
Link to website / documentation for secretariat	http://www.argo.ucsd.edu/Argo_Project_Office.html		http://emso.eu/ https://www.pmel.noaa.gov/gtmba/pirata http://www.rapid.ac.uk/rapidmoc/	https://www.jcomm.info/index.php?option=com_oe&task=viewDocumentRecord&docID=2017
Identified users (numbered list)	(1) Australia: CSIRO, BMRC (2) Canada: DFO, ECCC, DND (3) France: Mercator Ocean (4) Germany: ZMAW (5) India: INCOIS (6) Japan: JMA (7) Norway: MyOcean (8) UK: ECMWF, NCOF, Met Office (9) USA: NOAA.		(1) OceanSITES (2) EMSO (3) RAPID (4) PIRATA	(1) ICOS see above (2) Weather services (3) Scientific community
Products required by stakeholders (using number of stakeholder, as above)	1-9 for weather forecasting		Essential Ocean Variables	1-3 More EOV measurements and good data quality control
EOV measurements required	The floats can record data from supplied sensors	Gliders can carry a payload similar to an ARGO float and so can measure the main physical and biogeochemical EOV's if equipped with sensors	All whenever possible	Increasing number of EOV's measured as sensors developed.
Other measurements required		Standard measurements are Conductivity, temperature and depth	None	
Technology developments required or beneficial (details)	Sensors for EOV's still in infancy for some variables	The gliderport network must be set up, and it is identified in the GROOM document above. The other requirements are for sensors to measure the EOV's as is the case with BG-ARGO	Effective anti-fouling techniques, more reliable sensors and samplers.	Need a wider roll out of the Automated Weather Stations (AWS). There are issues around placing of these on ships so care must be taken when looking at the data.

Current governance details	Europe has an ARGO ERIC	Aim to form a Glider European Research Infrastructure (GERI)	Governance split between EMSO_ERIC, RAPID, PIRATA and some separate countries	
Governance plans / potential developments Inc. linking to GOOS / GEO	ARGO is embedded in the GOOS/GEO networks	Plan to link to GOOS	In due course it is hoped that EMSO ERIC will become the coordinating body for European fixed point observations. EuroGOOS will have an MoU with EMSO to reduce complexity and increase strength of the community. Highly desirable for PIRATA and RAPID to become part of this and for other countries to join the ERIC.	The data from the SOOP provide an important contribution to GOOS and is integrated into the GOOS.
Overview of internationalisation and roadmap / plans	Argo Information Centre in Toulouse part of JCOMMOPS	The roadmap has been developed and aims to link to ESFRI in Europe. The ultimate plan for the network in Europe would be to form an ERIC	Discussions are in place to encourage additional member states to join EMSO	The aim is to encourage operators to carry the AWS's and other instruments and report to the SOOPIP. There is no overall roadmap that could be located.
Business case developed (Y/N)	Y	N	N	N
Finance for establishing network (Y/N & details)	Yes at the national level	N	N (almost all observatory funding is from member states.)	Technical coordinator paid for by JCOMM.
Funding / resources for pilot (Y/N & details)	N/A	National Governments have invested and plan to sustain their glider networks, e.g. UK MARS programme	N	N
Sustained Funding / resources? Details	Yes at the country level and funds to run the office of the ERIC	At the national level with a proposed small budget to integrate and link to GOOS	Funding is from Member States	Not known
Link to website / documentation for business plan	Done at the country level	Not available	Not available	Not available
Network aware of data best practice	Yes	Yes	Yes	Yes
Network applying data best practice	Yes	Yes	Yes for most data	Yes
Metrology best practice developed: Y/N for each measurement	Yes	No	Mainly yes	Yes in as much as training is given on the shipboard equipment, and data is collected to bodies in the UK and Germany.
Metrology best practice document links / attachments	http://www.argodatamgt.org		Mainly yes	
Pilot network implementation?	No	Yes	No	No
Roadmap to mature network?	Country level and BG ARGO roadmap	Yes	No	No
Details / link to roadmap	http://www.oceanobs09.net/proceedings/cwp/cwp39/	http://www.groom-fp7.eu/lib/exe/fetch.php?media=public:deliverables:groom_final_report_publishable.pdf		
Estimated timeline to maturity (years)	1-3	4-7	4-7	1-3

Sector	Biological observing networks			
Network	*Genomic and meta-genomic*	*Ocean tracking network*	*Kelp Ecosystem Ecologic Network*	*Marine Biodiversity Observation Network*
Organised community (Y/N)	No	Yes	Yes	Yes
Website (link)	Not available	http://oceantrackingnetwork.org	http://kelpecosystems.org	https://geobon.org/networks/thematic-bon/mbon/
Organisation document link / attachment	Not available	http://oceantrackingnetwork.org/about/#management	Started as a product from a group of researchers that got together to determine the trends of kelp forests around the world	Linked to GEO BOM
Secretariat established? (Y/N)	No	Yes	No	N (secretariat for GEO BOM)
Link to website / documentation for secretariat	Not available	http://oceantrackingnetwork.org/about/#management		https://geobon.org/about/contact/
Identified users (numbered list)	(1) UN Environment, WCMC, GEOBON, MBON and related agencies (2) G7 Augmented Observatories initiative (2) DNAquaNet EU Cost action (3) The Earth Science Information Partnership (ESIP) (4) The Biodiversity Information Standards (TDWG) consortium (5) Genomic Standards Consortium (GSC)	(1) Scientists (2) Managers (3) Policy-makers (4) Industry (5) Indigenous and coastal communities	(1) Scientists (2) Managers (3) Policy-makers (4) Industry (5) Indigenous and coastal communities	(1) Scientists (2) Managers (3) Policy-makers (4) Industry (5) Indigenous and coastal communities
Products required by stakeholders (using number of stakeholder, as above)	(1) robust indicators and indices based on genomic observations (2) concepts for the implementation of genomic observations in operational observatories (3) omics based data products, e.g., GIS layers (4) community-agreed data and data exchange standards (5) community-agreed metadata standards	Not clearly identified	Biogeochemical and physical in this ecosystems	1) EBVs, Methods

EOV measurements required	Genomic observations are needed to address the emerging EOV 'Microbial biomass and diversity' but will also be helpful for several other biology/ecosystems EOVs (e.g., addressing phyto- and zooplankton, benthic invertebrates)	Moving towards equipping the animals with sensors but limited at the moment. Currently relies on standard physical oceanographic measurements at the local/basic scale where available	Macroalgae extent	All biological EOVs or EBVs
Other measurements required	All measurements that describe the physicochemical environment, including physical water mass characteristics and circulation, as well as the biogeochemical conditions (e.g., nutrients, DIC...)	All measurements that describe the physicochemical environment, including physical water mass characteristics and circulation, as well as the biogeochemical conditions (e.g., nutrients, DIC...)	All measurements that describe the physicochemical environment, including physical water mass characteristics and circulation, as well as the biogeochemical conditions (e.g., nutrients, DIC...)	All measurements that describe the physicochemical environment, including physical water mass characteristics and circulation, as well as the biogeochemical conditions (e.g., nutrients, DIC...)
Technology developments required or beneficial (details)	(1) operational in situ sequencer (2) In situ time series sampler with proper sample fixation	More sensors for EOV's	Mostly done by divers, but some populations can be monitored by satellite	e DNA, imaging, hydroacoustics, other
Current governance details	Emerging community	http://oceantrackingnetwork.org/about/#management	Coordinator: Jarret Byrnes. Coalition of the wiling. Regional coordinators	3 co-chairs of MBON. Part of GEO BOM
Governance plans / potential developments Inc. linking to GOOS / GEO	There are several initiatives addressing specific aspects of the network enhancement, e.g., improvement of genomic technologies and application to produce environmental indices (GEOBON,MBON, DNAqua-Net, DNAqua-Net, Genome Canada...) and facilitation of genomic data integration, discovery and comparison incl. through community-driven standards (TDWG, GSC). Together with Agriculture and Agri-Food Canada, AtlantOS started to build a Global Omics Observatory Network (GLOMICON) by hosting a seeding workshop and different follow-up activities (e.g., integrating with GEO BON and GEOSS).		Link with GEO BOM/MBON	Part of GEO BOM (thematic network)
Overview of internationalisation and roadmap / plans	Planning is at an early stage. From the beginning at the seeding workshop the AtlantOS-driven GLOMICON initiative included several international key initiatives and institutions in the field (e.g., GEO BON/MBON, TARA Oceans, NEON, NOAA, the GSC, the Earth Microbiome Project, the Genomic Observatories Network)		This started at global level with researchers from Australia, Africa, South and North America and Europe.	Created as an international "coalition of the willing" or community of practice bringing together existing networks that include biological/biodiversity observations
Business case developed (Y/N)	N	Not clearly identified	No	In development
Finance for establishing network (Y/N & details)	N	Yes. Most of the funding is from the Canadian Government with limited funds provided at the National level for the national programmes.	Initial funding from NCEAS. No regular funding now	Some sub-projects funded (P2P in the Americas, MBON US). Regular funding for secretariat of GEO BOM by IDIV, Germany and Canada.
Funding / resources for pilot (Y/N & details)	N	Yes. The project is beyond the pilot stage.	Still in pilot phase	Yes: MBON US (funded by NASA, NOOA) and Pole 2 pole in the Americas
Sustained Funding / resources? Details	N, some funding from AtlantOS and Agriculture and Agri-Food Canada but GLOMICON so far depends on voluntary contributions by members	Yes for the underlying Canadian programme.	No	Only for GEO BOM Secretariat
Link to website / documentation for business plan	N/A	N/A	N/A	N/A
Network aware of data best practice	Yes	Yes		Yes
Network applying data best practice	N, so far, most apply individual methods that are tailored to the local ecosystem characteristics and scientific needs. Sample exchange and method comparison activities are initiated as part of WP6	Yes	Methods for monitoring decided by the network	No

Metrology best practice developed: Y/N for each measurement	N. A future initiative of GLOMICON will be to map genomic observation activities. Based on that, current methodologies will be collected. A first step in AtlantOS will be the compilation of methods from large initiatives (e.g., Earth Microbiome Project, Tara Oceans, Ocean Sampling Day) for access via the IODE-hosted Ocean Best Practices archive and as a contribution to D6.4	Unknown	N/A	No
Metrology best practice document links / attachments	N/A	The projects applies the OBIS-ENV-DATA system. http://iobis.org/manual/dataformat/ The data policy can be found at the following website: https://members.oceantrack.org/data/policies	N/A	N/A
Pilot network implementation?	N/A	Beyond pilot	Yes	Yes
Roadmap to mature network?	Will be developed as part of the GLOMICON initiative started within AtlantOS	N/A	N/A	N/A
Details / link to roadmap	N/A		None as yet	Not available
Estimated timeline to maturity (years)	4-7	4-7	7-10	4-7

Sector	Industrial infrastructure opportunities	
Network	*Telecomm cables*	*Offshore installations*
Organised community (Y/N)	Yes	Yes in part for the oil and gas industry, through the SERPENT project. Equinor (formerly StatOil) operate the LoVe observatory.
Website (link)	https://www.itu.int/en/ITU-T/climatechange/task-force-sc/Pages/default.aspx	http://www.serpentproject.com https://love.statoil.com/Documentation/Overview
Organisation document link / attachment	The Green cables initiative is part of the wider International Telecommunications Union	http://www.serpentproject.com/partners Little on the Equinor website
Secretariat established? (Y/N) Link to website / documentation for secretariat	Yes The secretariat is the ITU secretariat that covers the whole organisation https://www.itu.int/en/general-secretariat/Pages/default.aspx	No
Identified users (numbered list)	(1) Governments (2) Climate and weather agencies (3) Tsunami warning centres and agencies (4) Earthquake information and response agencies (5) Disaster risk reduction agencies (6) Submarine cable telecommunication companies (7) Scientific organisations	(1) Scientists (2) Conservation groups (3) General public
Products required by stakeholders (using number of stakeholder, as above)	Not clearly identified (3) Tsunami warning system proposed by NOAA	Not clearly articulated
EOV measurements required	Dependent on the sensors developed. Initial proposed measurements are for temperature, pressure and acceleration on the demonstration pilot.	Currently no sensors beyond camera and video work on the SERPENT project. The LoVe observatory has still cameras alongside C, T, D, turbidity and chlorophyll
Other measurements required	All measurements that describe the physicochemical environment, including physical water mass characteristics and circulation, as well as the biogeochemical conditions (e.g., nutrients, DIC...)	N/A
Technology developments required or beneficial (details)	The communications system and sensors are off the shelf systems, the integration onto the cables is needed. The integration of the test cable system to a host cable is needed for the demonstration pilot.	N/A

Current governance details	UNCLOS regulations around cable deployments	SERPENT project run by a group of scientific organisations and universities in association with most of the major oil and gas companies. The LoVe observatory is funded by Equinor through IMR in Bergen, Norway.
Governance plans / potential developments Inc. linking to GOOS / GEO	No clearly articulated plans at present.	Not at present
Overview of internationalisation and roadmap / plans	https://www.itu.int/dms_pub/itu-t/oth/4B/04/T4B040000150001PDFE.pdf	Not developed
Business case developed (Y/N)	Yes	No
Finance for establishing network (Y/N & details)	No but proposed that the UN or country funding is in place. It will probably not be funded by industry.	No
Funding / resources for pilot (Y/N & details)	https://www.itu.int/en/ITU-T/climatechange/task-force-sc/Documents/JTF%20Report%20Green%20Cable%20Funding%20Study.pdf This document identifies the costs associated with a pilot demonstration project.	SERPENT is funded through national projects to the scientific research groups, ROV footage and access given by the industrial partners. The LoVe observatory is funded via Equinor and data is freely available to science and non-commercial users
Sustained Funding / resources? Details	Not known at this point in time	Not known
Link to website / documentation for business plan	N/A	N/A
Network aware of data best practice	Yes	No
Network applying data best practice	No. Intending that data practices are passed to the users of the sensors.	N/A
Metrology best practice developed: Y/N for each measurement	No	Little information on data quality control and general metrology
Metrology best practice document links / attachments	N/A	N/A
Pilot network implementation?	On going	N/A
Roadmap to mature network?	N/A	N/A
Details / link to roadmap	None as yet	N/A
Estimated timeline to maturity (years)	7-10	4-7

Sector	Other	
Network	*Seafloor mapping*	*Fisheries and zooplankton observations*
Organised community (Y/N)	Yes	Yes
Website (link)	https://seabed2030.gebco.net	http://www.ices.dk/marine-data/data-portals/Pages/acoustic.aspx
Organisation document link / attachment	https://seabed2030.gebco.net/about_us/	
Secretariat established? (Y/N)	Coordinated through one Global Centre and four Regional Centres	No but organized through the ICES working group on Fisheries Acoustics Science and technology
Link to website / documentation for secretariat	https://seabed2030.gebco.net/about_us/	http://www.ices.dk/community/groups/Pages/WGFAST.aspx
Identified users (numbered list)	(1) Scientists (2) Industry (3) Environmental organisations	(1) Fisheries biologists (2) Advisory groups
Products required by stakeholders (using number of stakeholder, as above)	(1+2+3) Bathymetry and associated variables (e.g. slope), backscatter data	Yes, input to fisheries assessment models (for fish)
EOV measurements required		The vessels usually collect a wide range of auxiliary information
Other measurements required	Sound velocity profiles (temperature + salinity) for the study area	

Technology developments required or beneficial (details)	Autonomous mapping approaches must be promoted. E.g. the development of autonomous surface vehicles or autonomous underwater vehicles that have a longer service period and are more independent from ships. Furthermore, it is essential that options for big data transfer from the open ocean are evaluated and suitable solutions established, e.g. via data taxis, SOOPs, mobile networks, satellites, submarine cables etc.	Mature
Current governance details		ICES WGFAST http://ices.dk/sites/pub/Publication%20Reports/ICES%20Survey%20Protocols%20(SISP)/SISP-4%20A%20metadata%20convention%20for%20processed%20acoustic%20data%20from%20active%20acoustic%20systems.pdf#search=SISP-4
Governance plans / potential developments Inc.. linking to GOOS / GEO		
Overview of internationalisation and roadmap / plans	https://seabed2030.gebco.net/data_centers/documents/seabed_2030_roadmap_v10_low.pdf	
Business case developed (Y/N)		
Finance for establishing network (Y/N & details)	Nippon Foundation and GEBCO	Surveys are run by ICES member states
Funding / resources for pilot (Y/N & details)	The Atlantic Seabed Mapping International Working Group (ASMIWG) is a pilot project pilot funded by AORAC-SA and AtlantOS.	National funding
Sustained Funding / resources? Details	Yes Nippon foundation	Yes
Link to website / documentation for business plan		N/A as at the national level
Network aware of data best practice	Yes	Yes

Network applying data best practice	Best practice plan in development	
Metrology best practice developed: Y/N for each measurement		
Metrology best practice document links / attachments		Not available
Pilot network implementation?	Beyond pilot	Beyond pilot
Roadmap to mature network?		Not available
Details / link to roadmap		Not available
Estimated timeline to maturity (years)	1-3	4-7

Table 2. Summary of all of the emerging networks surveyed for AtlantOS D6.2.